

****FULL TITLE****
*ASP Conference Series, Vol. **VOLUME**, **YEAR OF PUBLICATION***
****NAMES OF EDITORS****

Newly arising problems in the research of SU UMa-type dwarf novae from VSNET collaborations

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Abstract. Our research on variable objects based on the VSNET collaborations has achieved much progress in understanding the nature of many kinds of phenomena. Many problems have appeared, instead. Among them, we here review three newly arising problems in the research of SU UMa-type dwarf novae: 1) how do EI Psc and V485 Cen evolve as a cataclysmic variable?, 2) is the early superhump a particular phenomenon for WZ Sge-type dwarf novae?, and 3) what parameters determine variations of the superhump period?

1. Introduction

Cataclysmic variable stars (CVs) are binary systems of a white dwarf primary, and a late-type main-sequence secondary star. The surface gas of the secondary star is transferred to the white dwarf as the Roche-lobe overflow via the Lagrangian point (L1). The transferred gas forms an accretion disk around the white dwarf, although white dwarfs in some systems have magnetic fields strong enough to interrupt the disk formation.

Various kinds of photometric variability are observed in CVs, such as, flickerings, quasi-periodic oscillations, orbital humps, outbursts, nova explosions, and so on. Most of these variabilities are related to the mass transfer and accretion phenomena. Dwarf novae are a group of CVs, which (quasi-)periodically cause large-amplitude outburst (typically 2-5 mag).

We have been doing research on activities in a variety of variable objects, such as, dwarf novae, X-ray binaries, GRBs, and so on, with many amateur/professional astronomers all over the world, mainly by monitoring many objects, exchanging information, and coordinating observational campaigns on Variable Star NETwork (VSNET) according to circumstances (Kato et al. 2004b). Much progress in understanding the nature of many kinds of variable objects and phenomena has been achieved. Many problems have appeared, instead. Among them, we will review three newly arising problems in the research of SU UMa-type dwarf novae: 1) how do EI Psc and V485 Cen evolve as a cataclysmic variable?, 2) is the early superhump a particular phenomenon for WZ Sge-type dwarf novae?, and 3) what parameters determine variations of the superhump period (P_{sh})?

2. Three new problems

2.1. How do EI Psc and V485 Cen evolve as a cataclysmic variable?

This problem was highlighted by Uemura et al. (2002a, b). EI Psc is a counterpart of an X-ray source 1RXS J232953.9+062814. The dwarf nova nature of

this object was proved by optical spectra showing hydrogen and helium emission lines and TiO absorption bands (Hu et al. 1998). The first outburst of EI Psc was reported to VSNET by P. Schmeer on 2001 November 3. An observation campaign was promptly coordinated by Uemura et al. They detected superhumps during this outburst, revealing that EI Psc is an SU UMa star.

The most interesting point is that EI Psc has a very short orbital and superhump period of 64.2 min and 66 min (Uemura et al. 2002a; Thorstensen et al. 2002), respectively. This orbital period breaks the so-called “observed period minimum” of 78 min. Moreover, its relatively bright quiescence magnitude and spectrum in quiescence suggest that this star has a relatively high rate of the mass transfer from a mid K-type secondary star. This does not agree with the standard evolution theory telling that dwarf novae around the period minimum have a very low-mass secondary of the late M- or early L-type, and the mass transfer rate is quite low. With the analogous system of V485 Cen (see Olech 1997, and references therein), which was somewhat ignored due to its uniqueness, these objects establish the first subpopulation in hydrogen-rich cataclysmic variables below the period minimum.

Podsiadlowski et al. (2003) predicted that a cataclysmic variable whose secondary star has a hydrogen-exhausted core has a shorter period minimum and the secondary is more luminous than in a CV having a normal secondary star. The peculiarity of EI Psc and V485 Cen is generally consistent with this view. As suggested by Podsiadlowski et al. (2003), the group of EI Psc and V485 Cen may be on the evolution path to the double-degenerated AM CVn-type binaries (Uemura et al. 2002b).

SDSS J013701.06–091234.9, the most recently discovered SU UMa-type star (Imada et al. in this volume; Imada et al. 2006), seems to have intermediate properties between the normal SU UMa stars and the EI Psc/V485 Cen group in terms of the orbital period, mass transfer rate, type of the secondary star. This may be a bridging object between these two classes.

2.2. Is the early superhump a particular phenomenon for WZ Sge-type dwarf novae?

WZ Sge stars are a small group of enigmatic SU UMa-type dwarf novae (see Kato et al. 2001, and references therein). These stars have the following common outburst properties: 1) very long recurrence cycles of the outburst (years to decades), 2) large outburst amplitudes over 6 mag, 3) long outburst durations (including the rebrightening phase and long fading tail) up to 100 days, and 4) no (or only few) normal outburst between successive two superoutbursts. While the outburst behavior of normal dwarf novae are well explained by the thermal-tidal disk instability model, that of WZ Sge stars still remains a big challenge (for a review, Osaki 1996).

However, another common phenomenon, called ‘early superhumps’, has been recently recognized. The early superhumps are observed before emergence of the (normal) superhumps, and have doubly peaked shapes while the (normal) superhumps have singly peaked shapes. The period of the early superhump is quite close to the orbital period [Note that the early-superhump period observed during the 2001 superoutburst in WZ Sge was shorter by 0.05% than the orbital period. This difference was small, but significantly larger than the

error.]. Early superhumps have been observed all the four definite WZ Sge stars intensively observed from the early phase of superoutbursts. They are WZ Sge itself (Ishioka et al. 2002; Patterson et al. 2002), AL Com (Kato et al. 1996; Ishioka et al. 2002), HV Vir (Kato et al. 2001; Ishioka et al. 2003), and EG Cnc (Matsumoto et al. 1998; Kato et al. 2004a).

There is another SU UMa-type dwarf nova where early superhumps were observed. It is RZ Leo whose SU UMa nature was revealed during the 2000-2001 superoutburst (Ishioka et al. 2001). The following features of RZ Leo are common to the canonical WZ Sge stars: 1) the recent low frequency of the outburst (the 2000 superoutburst is only one outburst caught in 1995-2005), 2) the large outburst amplitude of ~ 6 mag, and 3) the long outburst duration of > 40 days. RZ Leo is, however, different from other WZ Sge stars in the three points: 1) the ‘long’ orbital period of 0.0765(2) d (Mennickent and Tappert 2001) (cf. ~ 0.058 d in other WZ Sge stars), 2) the large excess (3.3%) of the superhump period to the orbital period (cf. $\sim 1\%$ in other WZ Sge stars), and 3) the existence of a period of a ‘short’ outburst cycle (one outburst every year in 1987-1990). The superhump excess has a tight relation with the mass ratio ($q = M_2/M_1$), and the large superhump excess of RZ Leo suggests the mass ratio of RZ Leo (~ 0.14) to be about two times larger than that of other WZ Sge stars.

The current low outburst frequency and behavior during the 2000-2001 superoutburst support RZ Leo to be a WZ Sge-type dwarf nova. The variation of the outburst frequency implies a change of the mass transfer rate. RZ Leo may be presently in the ‘WZ Sge phase’ with a low mass transfer rate. If this is the case, it implies that the orbital period and mass ratio are only weakly related to the WZ Sge phenomena, and that the mass transfer rate is the unique parameter to distinguishes the normal SU UMa stars and the WZ Sge systems.

Judging from the observations available at this time, there is no negative evidence for that the early superhump is a particular phenomenon for WZ Sge-type dwarf novae. The samples, however, must not be enough to conclude this problem. We should continue to monitor RZ Leo and to start coordinated observations of WZ Sge/SU UMa systems in outburst as early as possible.

2.3. What parameters determine variations of the superhump period?

The superhump period had been considered to gradually decrease, or at least remain constant, during one superoutburst, till 1996. However, since the discovery of a P_{sh} increase in the 1996 superoutburst in SW UMa (Semeniuk et al. 1997; Nogami et al. 1998), the same phenomenon have been observed in some dwarf novae (Imada et al. 2005; Uemura et al. 2005, and references therein).

Figure 5 in (Imada et al. 2005) summarizes the time derivatives ($P_{\text{dot}} \equiv \dot{P}_{\text{sh}}/P_{\text{sh}}$) of the superhump period ever measured. In this figure, we can see a trend that dwarf novae having a shorter P_{sh} have a high probability that the superhump period is observed to increase.

Based on Osaki and Meyer (2003), this phenomenon is interpreted in the following way. In the SU UMa-type dwarf novae having a relatively long orbital period and a relatively high mass transfer rate, the 3:1 resonance radius in the accretion disk is very close to the tidal truncation radius, and the mass is not much accumulated by a superoutburst due to frequent occurrence of the

outburst. Then, the eccentric waves arising at the 3:1 resonance radius can not spread outwards, but do inwards. The superhump period thus decrease. On the other hand, in short period systems infrequently causing outbursts, the 3:1 resonance radius is significantly smaller than the tidal truncation radius, and the mass is much accumulated in the accretion disk. Then, enough mass spreads over the 3:1 resonance radius at the onset of a superoutburst, and the eccentric waves can propagate outwards. It is thus observed that the superhump period increases.

Uemura et al. (2005) observed in TV Crv that the superhump period increased during the 2001 superoutburst with no precursor, and the superhumps period remained almost constant during the 2004 superoutburst with a precursor. The existence of the precursor in the 2004 superoutburst suggests that the mass accumulated during quiescence was smaller before the 2004 superoutburst than before the 2001 superoutburst. These observations support the interpretation described above.

In conclusion, the orbital period and mass transfer rate should be important parameters for the variation of the superhump-period derivative. However, it has been recently observed that the superhump period remained constant, or might increase even in some SU UMa stars having relatively long orbital periods. In addition, some stars show interchanges of the increase/decrease trend of the superhump period (e.g. TT Boo, see Olech et al. 2004). There may be other parameter, for instance, the mass ratio, related to the variations of the superhump period. We still need more observations to fully solve this problem.

We are sincerely thankful to all the VSNET collaborators. This work is supported by Grants-in-Aid from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) (Nos. 16340057, and 17740105).

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